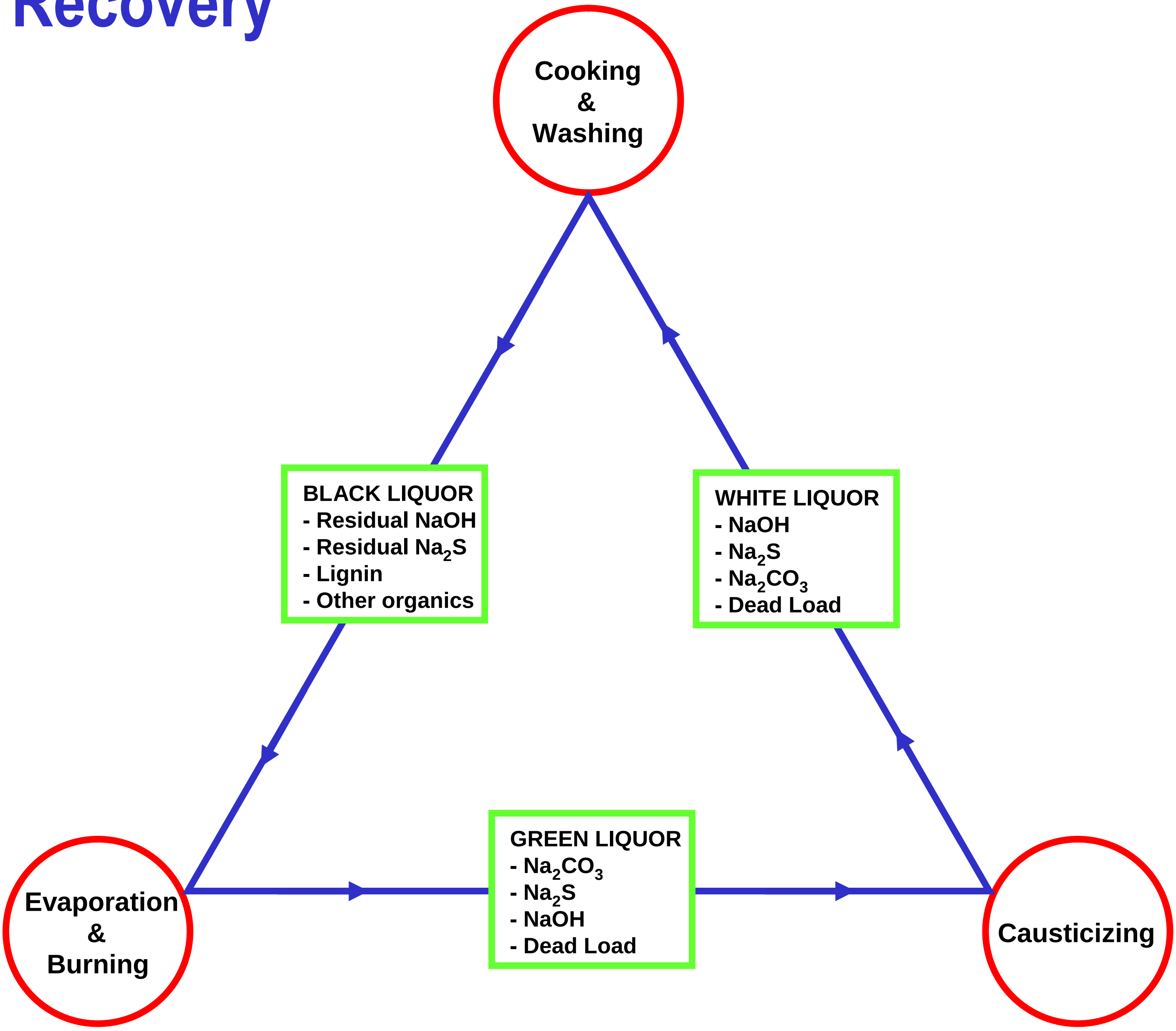
The *DURALYZER-NIR* ™ Series of Liquor Analyzers for Alkali Based Pulping and Recovery



CONMARK

Company Profiles

R. E. Hodges, LLC was founded in 2001 as a manufacturer of spectroscopic based measurement and control solutions for the process industries.

Spectroscopic based measurement solutions hold the key to solving most if not all of the difficult measurement applications in the process industries. R. E. Hodges, LLC was formed to develop these measurement and control solutions so traditional lab based testing for quality control can be replaced by real time online measurements coupled with advanced control methods. R. E. Hodges, LLC is unique compared to traditional spectrometer manufactures in the fact that we provide turnkey measurement and control solutions, based on spectroscopic methods, that have been tailored to suit the application. When an analyzer leaves our manufacturing facility it has been optimized for the application and is guaranteed to have minimal installation requirements and minimal continuing maintenance requirements. We are so confident in our products that we include a complete money back guarantee if the customer is not totally satisfied with the performance of the product.

Conmark Systems Inc. is an Atlanta, Georgia based corporation serving Pulp and Paper Industry in North America. Our goal is to drive continuous improvement in productivity, quality and efficiency of the pulp and paper mill operations and processes utilizing Six Sigma principles.

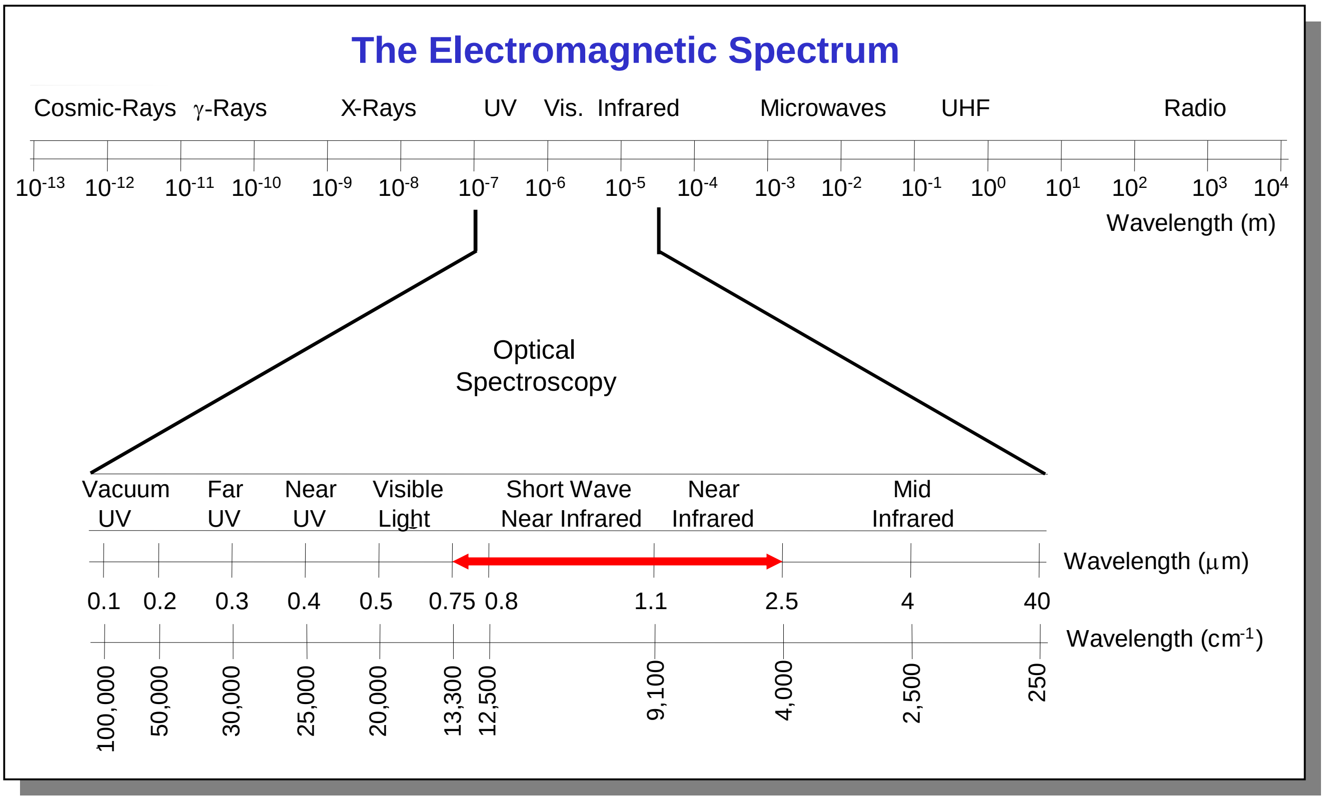
Conmark Systems Inc. is built around the belief that providing our customers with top-of-the ¬line products is essential, but not enough. Products alone do not constitute a solution. Therefore, they offer solution programs rather than individual products.
The programs are composed of industry expertise and applications, various leading edge products as Duralyzer Liquor Analyzer line, and the comprehensive customer support. The products incorporated into our solutions packages are specifically chosen to be the most suitable for tackling current problems in the Pulp and Paper Industry environment..

Contents

The Technology of Spectroscopy

Introduction

Chemical composition of process liquors is determined through the use of near-infrared (NIR) spectroscopy. This spectroscopic technique is a subset of a larger class of analytical techniques that fall in the category of optical spectroscopy techniques. The following figure shows the electromagnetic spectrum with the portion relating to optical spectroscopy expanded. Optical spectroscopy techniques have been used quite successfully for decades in the laboratory setting to analyze liquids, solids and gases composed of a multitude of chemical species. In the past twenty five years the development of miniaturized and durable electronic and optical components has allowed many of these techniques to be moved from the laboratory setting to the process environment. Development of new computational techniques along with the microcomputers to implement them have further advanced the use of spectroscopic techniques for both qualitative and quantitative analysis at the process.

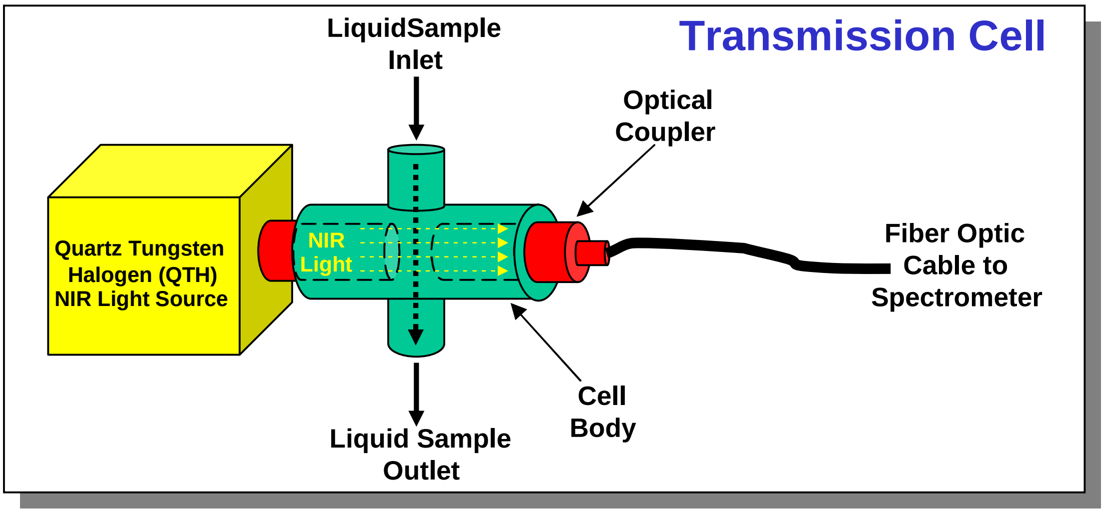


Near infrared (NIR) spectroscopy has many attractive features that make it ideally suited for process analysis (refer to the previous figure to see the NIR portion of the electromagnetic spectrum highlighted in red). Some of the key features of this technique include minimal sample preparation, remote sensing through the use of fiber optic cables and simple implementation using relatively inexpensive and highly robust components. In addition, a wide variety of optical attachments are available to interface NIR spectrometers to the sample under test. NIR spectroscopy has been successfully implemented in the agricultural industry for grain analysis, the pharmaceutical industry for raw material and final product quality control and analysis, and the dairy industry for milk and butter analysis. Other process industries that have had successful NIR applications include petrochemical, food and beverage, polymers and specialty chemicals. These applications are a testament to the utility of NIR spectroscopy as a general purpose process sensor. Many other applications are currently under development in all of the process industries based on NIR spectroscopy as the primary analytical technology.

The Technology of Spectroscopy

Sample Analysis

As mentioned previously there are a wide variety of optical attachments available to interface an NIR spectrometer to a sample for gathering spectral information about the sample. The most common attachment used for liquid analysis is a transmission cell. The following figure shows this arrangement.

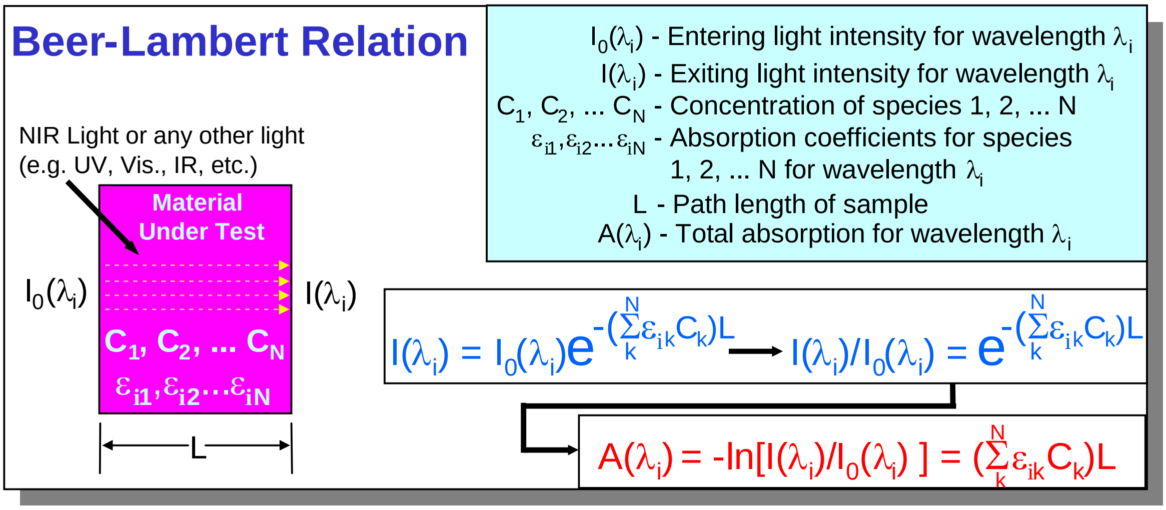


The transmission cell provides a means for NIR radiation to interact with the process sample while isolating the light source, fiber optic cable and spectrometer from the process. A typical transmission cell is composed of a body with appropriate sample inlet and outlet connections and a pair of optical couplers to deliver light to the sample and collect light after interaction with the sample. The optical couplers house a set of lenses to focus the radiation onto the tip of the fiber optic cable. The ends of the couplers in contact with the process sample have windows, usually sapphire, to provide a transparent optical path for the entering and exiting light as well as providing isolation from the process sample. Sapphire is usually the material of choice for the coupler windows due to its combination of hardness, chemical and heat resistance and transparency over a broad range of wavelengths.

The Beer-Lambert Relation

Light interacts with the sample in accordance with the Beer-Lambert relation. The details of this relation can be seen in the figure on the following page. According to this relation light intensity decays exponentially as it travels through the material. The rate of decay depends on the concentrations of the constituent species of the material and their corresponding absorption coefficients. The total amount of decay depends on the length of material the light crosses. The equation describing this phenomenon is highlighted in blue on the previous page. Total absorption at a particular wavelength can be computed by applying a logarithm to this equation. The resulting equation is highlighted in red on the previous page. The key observation to be made from this equation is that Absorption at a particular wavelength varies linearly with the concentrations of the constituent species. The path length, L, is fixed by the transmission cell, the absorption coefficients, ε_{ik}, depend only on the wavelength i and the molecular structure of species k of the material under test, therefore the Absorption will change only when the concentrations of the constituent species change. Another important observation to be made from the Absorption equation is that the Absorption at a particular wavelength depends on the concentration of ALL of the species that make up the sample under test. This is a major drawback for single wavelength instruments that are used to analyze multi-component materials. With these instruments the best that can be done is to select an observation wavelength that is highly absorbed by the component of interest while simultaneously minimizing the absorption of the other components.

Many times such a wavelength does not exist. This is an analogous situation to the application of conductivity for measuring effective alkali (EA) levels in white liquors. The white liquor conductivity is affected the most by the white liquor EA concentration but the sulfide and carbonate levels also have an affect on the conductivity. As a result, periodic recalibration of the conductivity meter is required to compensate for the effects of changing sulfide and carbonate levels.

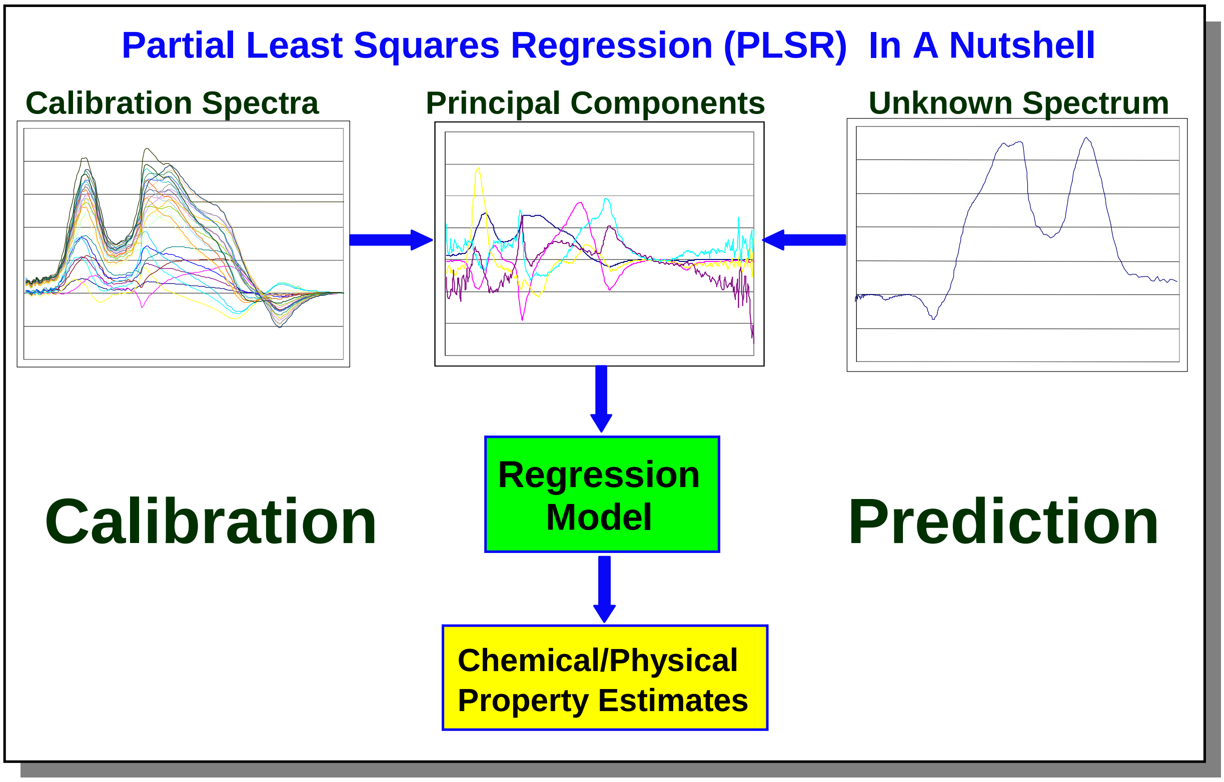


Converting Spectral Data to Chemical Data

Extraction of physical and chemical information from spectral data can be achieved through a number of regression techniques. The field of chemometrics has provided a number of mathematical techniques to deal with this issue. One of the most popular techniques in use for relating spectral data to physical and chemical data is partial least squares regression (PLSR). This technique takes a set of spectral data derived from samples with known properties (e.g. EA, AA, TTA, etc.) and builds a regression model. This regression model can then be used with spectra from unknown samples to predict the chemical/physical properties of the unknown. The figure on the following page shows a graphic summarizing the calibration and prediction operations.

In general a spectrum will have many more independent variables than available known samples which precludes the use of a standard regression approach. PLS reduces the size of the calibration spectral data set by computing a set of principal components. Any spectrum in the original data set can then be reproduced as some linear combination of these principal components. The principal components (PC's) are computed in such a way that a small number of PC's can be used to reproduce any given spectrum to any degree of precision desired. The original spectral data set is thus reduced to a small number of PC's and the corresponding coefficients required to reproduce each spectrum. Since the PC's are fixed for a given calibration set the coefficients now become the independent variables and represent the information content of the corresponding spectrum. At this point a standard regression model can be computed relating the spectral data to the properties of interest for the sample and the calibration is done. To predict an unknown sample a new spectrum is decomposed using the PC's from the calibration set. The information content of the new spectrum is reduced to a small number of coefficients based on the PC's from the calibration set. These coefficients are passed through the regression model to generate estimates of the desired physical/chemical properties of the sample.

The Technology of Spectroscopy



The above figure summarizes the PLSR technique for extracting quantitative data from spectral data. A set of known test samples are used to generate calibration spectra. The calibration spectra are reduced to a much smaller set of template spectra that can be used to reproduce any spectra in the original set through a weighted sum of the template spectra. The template spectra are fixed for a given calibration set so the weights or coefficients used for each calibration spectra contain all of the information contained in the original spectrum. Usually 10 or less template spectra are all that is required to reproduce the original calibration set to within measurement noise limits. A regression model can then be computed based on the coefficients instead of the original spectra. When the spectrum of an unknown sample is acquired the required coefficients are calculated to reproduce the unknown spectrum using the template spectra. These coefficients are then passed through the regression model to give a prediction of the chemical/physical properties of the unknown sample.

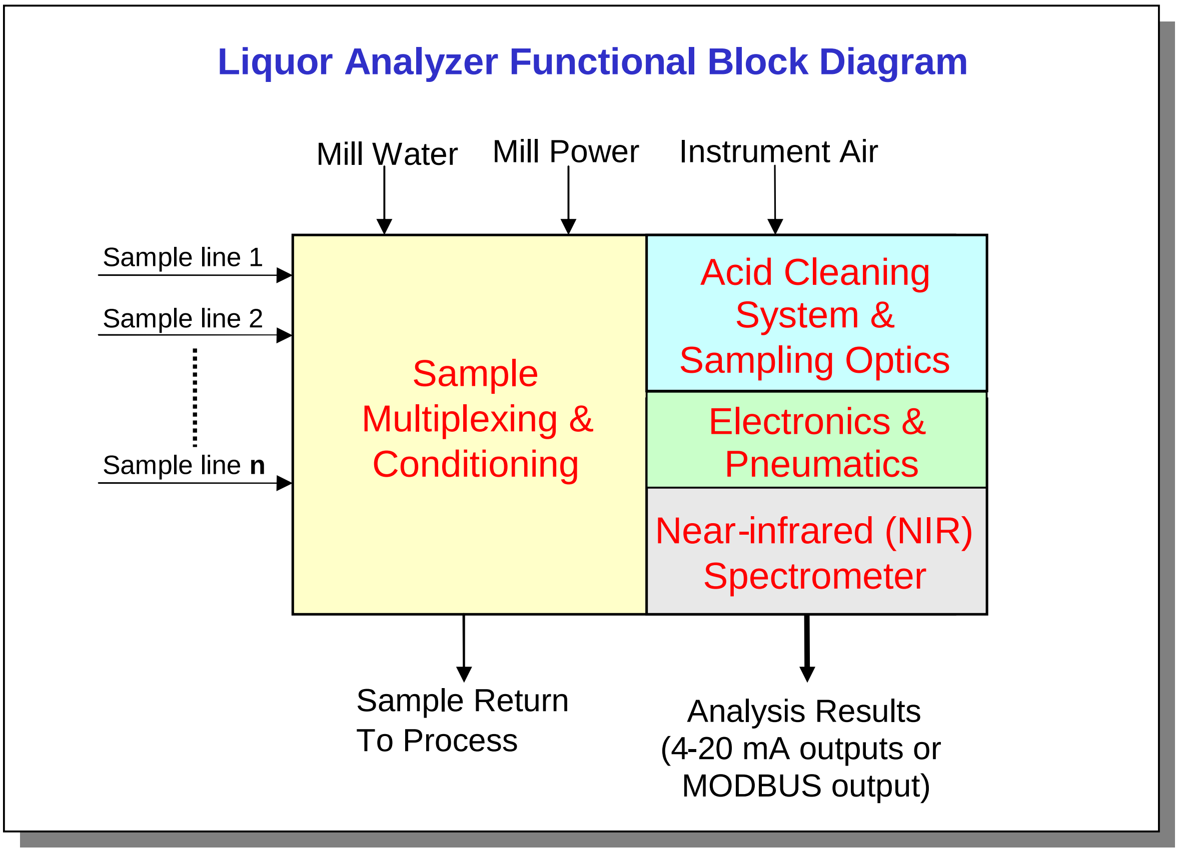
The *DURALYZER* Approach

Introduction

The ***DURALYZER-NIR*** series of liquor analyzers are like no other liquor analyzer solutions currently available. They represent a new generation of process liquor analyzers for alkali based chemical and semi-chemical pulping and recovery processes. These analyzers are the culmination of many years of research and development effort in both the laboratory and in the field, which has resulted in a family of systems with **unprecedented reliability, accuracy and simplicity**. These systems represent a comprehensive and highly cost effective solution to automated and manual liquor analysis.These analyzers define a new industry standard for liquor analysis systems that will become the final solution for these measurement applications.

DURALYZER-NIR Architecture

All automated systems use process sample extraction technology coupled with near-infrared (NIR) spectroscopy for sample analysis. As a result of this design, all analyzers share a common technology platform. This common technology platform has been engineered into a set of highly integrated, completely self-contained analyzers with the **lowest maintenance requirements ever achieved** for these applications. The following figure shows the general hardware arrangement for these analyzers.



The *DURALYZER* Approach

DURALYZER-NIR Architecture (Continued)

Each analyzer is divided into four functional blocks which results in a highly modular and reliable design. Each block is physically isolated from the other by individual cabinets. Following is a brief description of each block with the function that is served.

- **Sample Multiplexing & Conditioning** - This portion of the analyzer is composed of valves and peripheral hardware required to reliably deliver process samples to the analyzer for analysis.

- **Acid Cleaning System & Sampling Optics** - This portion of the analyzer is composed of the optical hardware required to interface the spectrometer to the sample under analysis. Additionally, an automated acid based cleaning system keeps the sampling optics free from scale buildup.

- **Electronics & Pneumatics** - This portion of the analyzer houses the electronic and pneumatic hardware required to interface the spectrometer to the sample multiplexing & conditioning and acid cleaning systems. IO point hardware and connections are also housed in this portion of the analyzer.

- **Near-infrared (NIR) Spectrometer** - The NIR spectrometer is the brains of the system. This device controls all aspects of sample extraction and preparation as well as the acid cleaning system. The spectrometer also analyzes the sample for chemical composition and then makes the results readily available through industry standard IO.

DURALYZER-NIR Installation Requirements

The ***DURALYZER-NIR*** series of liquor analyzers has been designed to simplify installation and minimize installation costs. Each analyzer is delivered with all components mounted on a rollable stainless steel frame. This arrangement yields a portable analyzer that can be easily moved to other installation locations if the need arises. The small footprint of the system allows for many options in terms of installation location. There are currently two analyzer footprints depending on the application. Pictures and dimensions of these two footprints are shown on the following two pages. The spectrometer is thermally stabilized using a vortex cooling system. Cool air from this system is fed to the other cabinets through the conduit connections providing a slight positive pressure within these cabinets. This guarantees that all system cabinets stay dry and clean inside. The result of this arrangement is that the **analyzer does not have any special housing requirements**, as compared to titration based systems, and can be installed close to the process sample points.

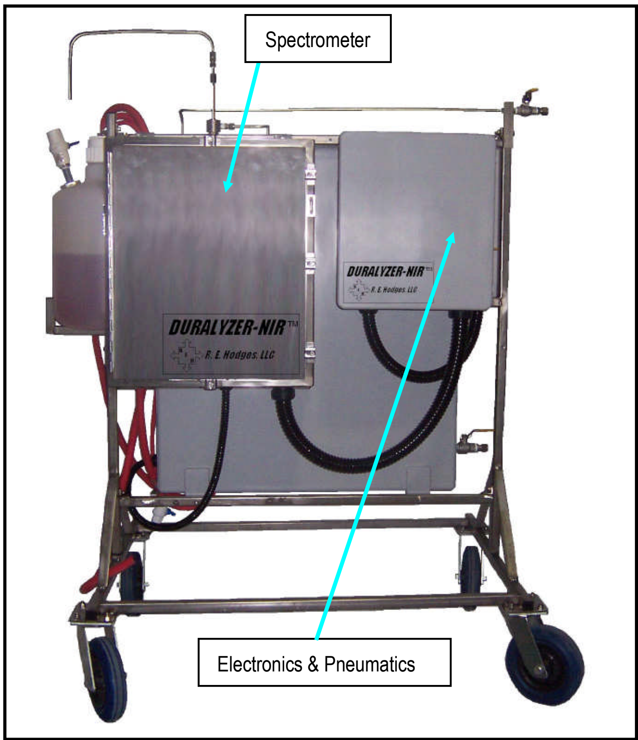
Utility requirements for analyzers are straightforward. Most analyzer models can run from a common 120V-60Hz single phase 15A service with line, neutral and ground connections. Some models requiring the high pressure backflush system will also need a 230V or 480V-3 phase 10A service. Instrument air is also needed for the cooling system and valve actuators. Required air pressure can range from 65-120 psi delivered in 1/2” tubing or larger. Mill water is also needed for sample line backflushing and spectrometer referencing. Mill water needs to be available at 40 psi or higher with 100 ppm or less of total suspended solids. If mill water quality is an issue samples can be sent to our facility for evaluation.

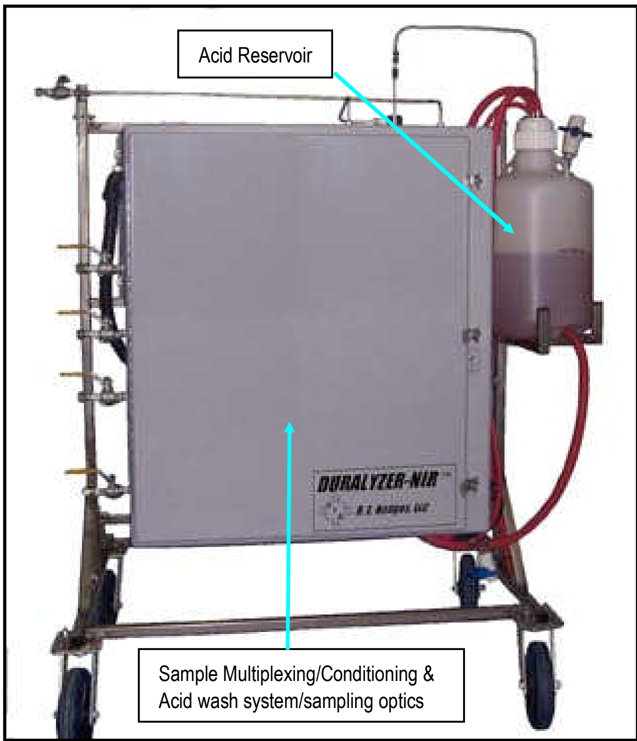
Sample line requirements vary depending on the application. Existing sample lines can be used in most cases, further reducing installation costs for the analyzer. Our technical department can provide sample line requirement details for a particular analyzer model to minimize installation costs.

The ***DURALYZER*** Approach

Footprint 1:

White/Green liquor analyzer & Dissolving/stab. tank analyzer configuration





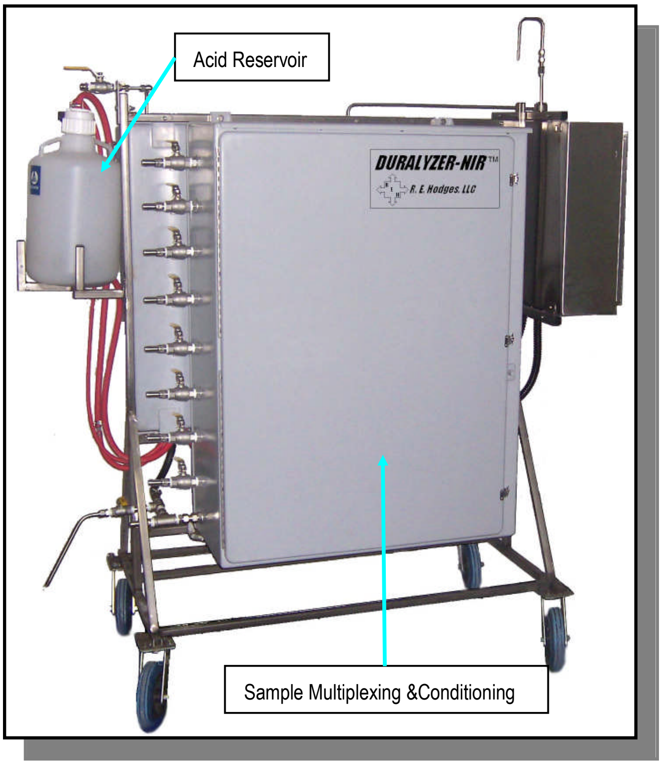
Dimensions: Footprint 1 Length x Width x Height - 52” x 32” x 48”

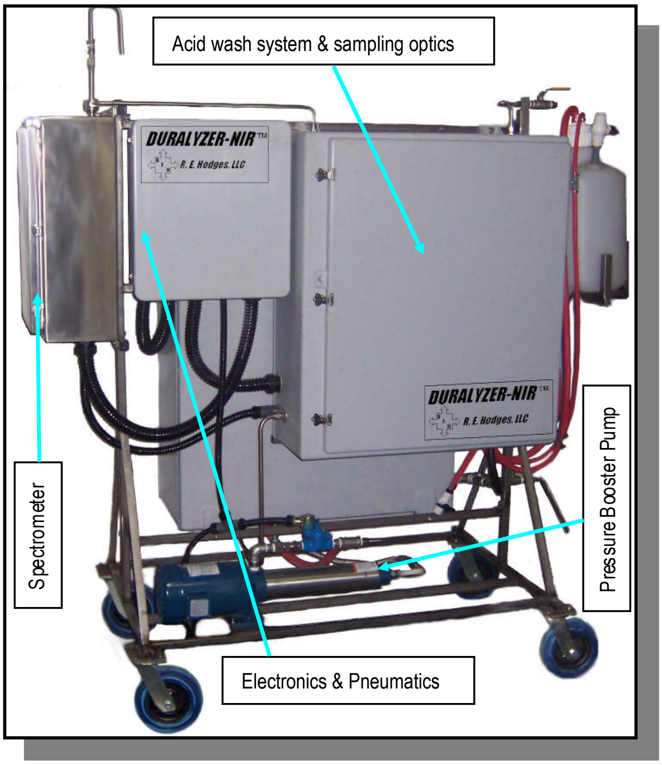
Weight: Footprint 1 270 - 320 lbs depending on configuration

The *DURALYZER* Approach

Footprint 2:

Causticizing analyzer & Digester analyzer configuration





Dimensions: Footprint 2 Length x Width x Height - 72” x 32” x 60”

Weight: Footprint 1 420 - 485 lbs depending on configuration

*The **DURALYZER** Approach*

***DURALYZER-NIR** Maintenance Requirements*

The ***DURALYZER-NIR*** series of liquor analyzers has been designed to minimize short term and long term maintenance requirements thus minimizing the cost of ownership. Scheduled maintenance requirements have been reduced to yearly bulb replacement in the light source and refreshing the optics cleaning acid on a one to six month schedule depending on the rate of scale buildup. Unscheduled maintenance has been greatly reduced by minimizing system component count as well as designing and implementing proprietary valves with a very high cycle life. A comprehensive set of alarm codes are available from the analyzer that will alert operators of any abnormal operation of the analyzer. In addition, a windows based diagnostics software package is provided that allows monitoring and testing of the analyzer through a TCP/IP ethernet connection from any PC on the network. All that is required is to assign the analyzer a TCP/IP address on the company intranet.

Remote dialup is also available for the analyzer. A dedicated phone line connection is **highly recommended** for any of the online analyzers so our technicians can call in and quickly diagnose any problems that may not be apparent to mill personnel. Periodic call-ins are made into the analyzers by our technicians to verify operation of the analyzer and alert mill personnel of any pending issues that need to be addressed. The dial up connection also allows us to update software, calibrations and operational aspects of the analyzer if the need arises.

Maintenance kits are available for all of the analyzers. These kits include burn in tested light sources, pneumatic actuator solenoids and solid state relays. Valve replacements can be purchased as separate items. Except for the proprietary sample valves, all other sampling system components are off the shelf items.

Definitions Of Acronyms

In the pages that follow, detailed information for each analyzer application is presented. The following list of acronyms along with their definitions are used in the description of the liquor chemistry.

NaOH - Sodium Hydroxide
Na_2S - Sodium Sulfide
Na_2CO_3 - Sodium Carbonate
Na_2SO_4 - Sodium Sulfate
Na_2SO_3 - Sodium Sulfite
$Na_2S_2O_3$ - Sodium Thiosulfate
Cl^- - Chloride Ion

EA – Effective alkali (NaOH + ½Na_2S)
AA – Active alkali (NaOH + Na_2S)
TTA – Total titrateable alkali (NaOH + Na_2S + Na_2CO_3)
REA – Residual effective alkali (residual NaOH + ½ residual Na_2S)
RAA – Residual active alkali (residual NaOH + residual Na_2S)
TDS – Total dissolved solids 100% * (Mass of dry solids/Mass of liquor)
TDD – Total dissolved deadload 100% * (Mass of (Na_2SO_4 + Na_2SO_3 + $Na_2S_2O_3$ + Cl^-)/TDS)
CE – Causticizing efficiency 100% * (NaOH/(NaOH + Na_2CO_3))
RE – Reduction efficiency 100%* (Na_2S/(Na_2S + Na_2SO_4))

Lab Based Liquor Analyzers

Introduction

Manual liquor testing has to be performed routinely for quality control purposes. Even if a mill has an online analyzer, periodic testing is still required to validate the online system. More often than not lab testing is the only measurement procedure available for process control decisions. The tedious and cumbersome nature of the standard ABC titration test for white, green and black liquors does not lend itself well to rapid manual testing. However, the nature of this testing procedure does lend itself well to induced errors if it is not performed with care and attention. As a result, liquor testing frequency is low and potentially biased and is usually performed at most once or twice per shift. The result of this practice is that much of the process variation is missed as well as the opportunity to reduce process variations. The ***DURALYZER-NIR*** bench top analyzer has been designed to overcome all of the issues associated with manual liquor testing, providing fast, reliable and accurate results with minimal operator involvement. The ***DURALYZER-NIR*** bench top analyzer provides the results of the standard ABC titration test, providing effective alkali (EA), active alkali (AA) and total titrateable alkali (TTA) measurements for white and green liquors. In addition, total dissolved solids (TDS) and total dissolved deadload (TDD) measurements are also provided. For black liquors, residual effective alkali (REA), residual active alkali (RAA), lignin and black liquor TDS measurements are provided. The ***DURALYZER-NIR*** bench top analyzer uses the same NIR technology that is used in our online analyzers. This instrument has been designed specifically for the somewhat harsh lab environments of the pulping and recovery areas providing many years of trouble free operation. The only required maintenance for the instrument is an annual replacement of the light source and occasional acid cleaning of the sample holders.

Application Details

Currently three lab based analyzers are available. The only difference in the three instruments is in the preloaded calibrations. The three configurations available are as follows:

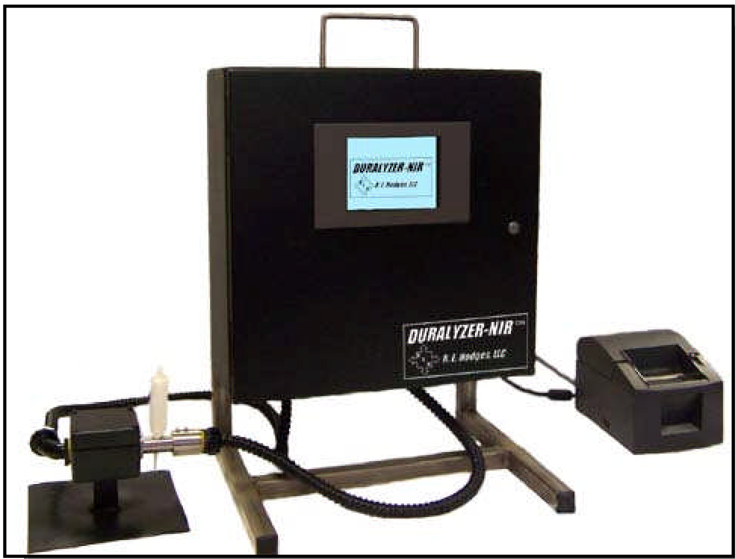
1) Dissolving tank area analyzer calibrated for green liquor and weak wash analysis.
2) Causticizing area analyzer calibrated for green liquor and white liquor analysis.
3) Digester area analyzer calibrated for white liquor and black liquor analysis.

All analyzers have a graphic touch screen setup for one button analysis once the sample is loaded. Test results are displayed on the screen and are printed out on the accompanying thermal printer. An optional IO module is available to write the results directly to the DCS through standard 4-20mA outputs or through a MODBUS connection.

DURALYZER-NIR .vs. Current Solutions

The standard ABC titration test requires multiple chemicals and lab equipment to implement. Titration chemicals such as certified HCl solution, formaldehyde, barium chloride and various color indicators are inconvenient and costly to maintain in the process testing lab. If a pH probe is used to monitor the titration then pH standards must also be kept on hand to calibrate the probe. In addition to the chemical requirements, precision volume measurement equipment for the sample and titration acid must be maintained in good working order and periodically calibrated. Bench top titraters have been implemented to automate the actual titration test. However, most of the same issues associated with the manual test are also present with the bench top titrater. At a minimum, titration acid and pH standards as well as precision volume measuring equipment are still needed for the bench top titrater. Most bench top titraters are based on the SCAN titration method. This method differs from the TAPPI standard ABC titration test in that formaldehyde and barium chloride are not used. Instead, a pH curve is generated as a function of the added titration acid. Inflection points on the titration curve are used to estimate the EA, AA and TTA values of the liquor sample. This technique can suffer from difficult to locate inflection points, especially for the AA point. The inflection point locations can vary with varying deadload concentrations, leading to erroneous concentration estimates. This effect is especially pronounced on the AA inflection point. The ***DURALYZER-NIR*** bench top analyzer completely eliminates all of the negative issues associated with manual and automated titrations by eliminating the chemical requirements, accurate volume measurement requirements and the effects of deadload variations. A table detailing the primary advantages of the ***DURALYZER-NIR*** bench top analyzer compared to current practices is given on the following page along with a picture of the bench top unit.

Lab Based Liquor Analyzers



DURALYZER-NIR Bench Top Analyzer .vs. Titration Methods		
Characteristic	**Titration Methods**	***DURALYZER-NIR*** **Bench Top Analyzer**
Available Measurements	3 - EA, AA, TTA	6 - EA, AA, TTA, TDS, TDD, Lignin
Measurement Technique	Inferred – Inflection point method based on pH titration curve[(1)]	Inferred – PLS regression technique based on TAPPI test methods (Regression model relating spectral signature to chemical composition)
Measurement Accuracy	Potential operator bias due to volume errors. Many opportunities to introduce errors	All operator bias removed since an accurate volume of sample is not needed. Almost no opportunities for induced errors.
Analysis Speed	Slow – Minutes[(2)]	Fast – 20 seconds
Maintenance	High – Replacement chemicals, pH probe calibration, premature titrater failure[(3)]	Very Low – Yearly light source replacement, occasional lab validation

1. SCAN titration method. More sensitive to deadload variations than standard TAPPI ABC test method.
2. Analysis speeds vary greatly from several minutes for bench top titraters to tens of minutes for a full manual ABC test.
3. Current commercial bench top titraters do not hold up well in the somewhat harsh process lab environment.

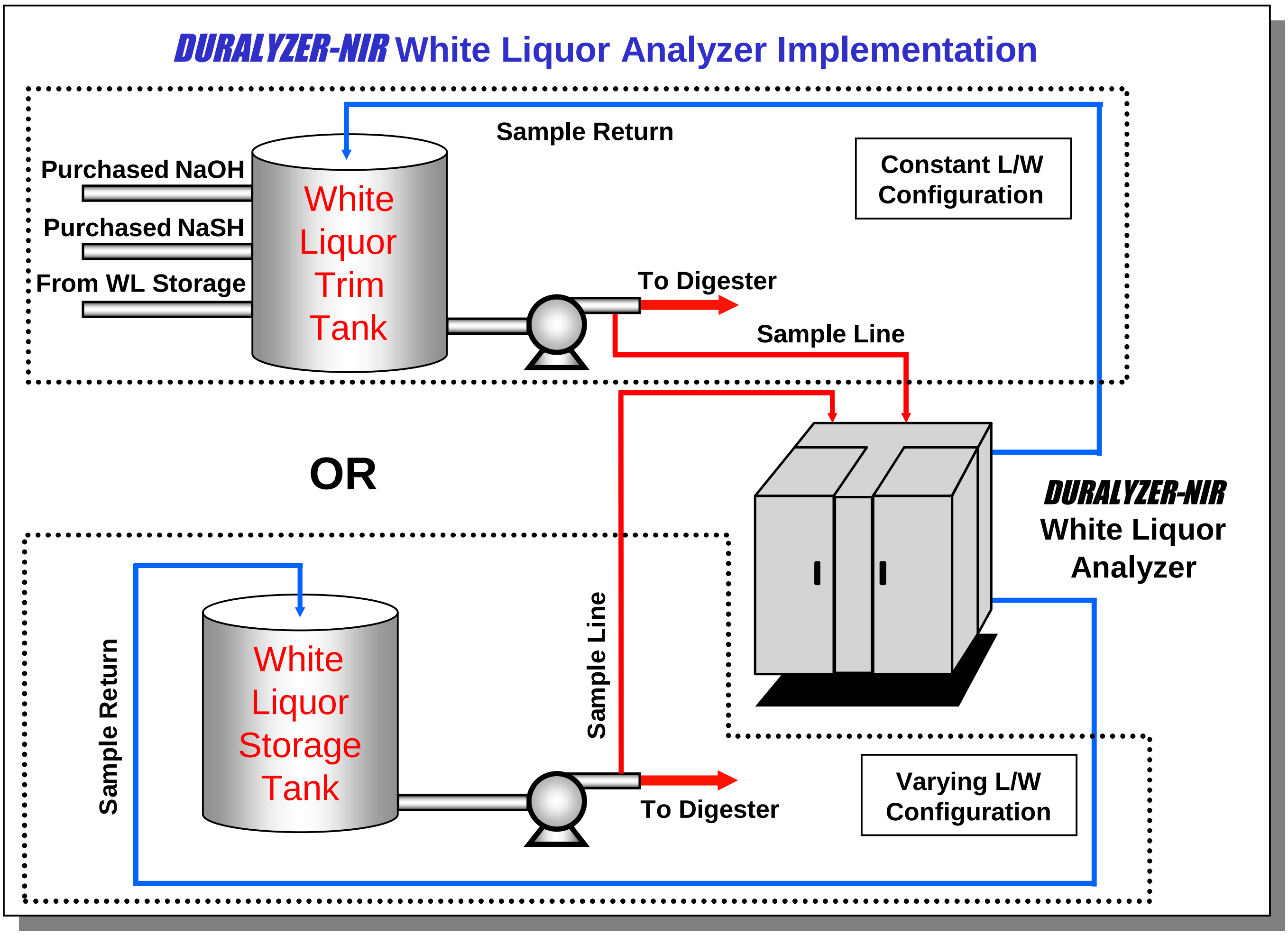
Online Liquor Analyzers
White Liquor Analyzer

Introduction
Reliable and accurate white liquor analysis for batch and continuous digesters is important for minimizing pulp quality variations. For both continuous and batch digesters white liquor composition needs to be accurately known to ensure that the correct effective alkali is charged for the given chip mass entering the digester. The two primary sources of variation that interfere with charging the correct amount of alkali on wood for batch and continuous digesters are chip moisture variations and white liquor variations. If white liquor composition is accurately known then one source of variation can be eliminated. With an online white liquor analyzer the white liquor can be trimmed in real time to meet target effective alkali and sulfidity levels allowing one to maintain a constant liquor to wood (L/W) ratio for a given alkali to wood ratio. Alternatively, variations in alkali to wood ratio induced by white liquor composition variations can be compensated for by only adjusting the liquor to wood ratio. Either approach requires an accurate online analysis of the cooking white liquor. The ***DURALYZER-NIR*** white liquor analyzer provides the required effective alkali (EA) and sulfidity measurements in a timely, accurate and reliable manner. Additionally, white liquor TTA, TDS and deadload levels are also available from the same analyzer.

Application Details
The graphic on the following page shows how the ***DURALYZER-NIR*** white liquor analyzer can be implemented for monitoring and controlling the white liquor charge to either batch or continuous digesters. Two possible configurations are given in the graphic. The white liquor trim tank configuration adjusts white liquor composition to a preset level so a constant liquor to wood (L/W) ratio can be maintained for a set alkali to wood ratio. The second configuration monitors white liquor composition without any means for adjusting the white liquor. This configuration requires that the alkali to wood ratio has to be adjusted by varying the liquor to wood (L/W) ratio. The goal of both configurations is to charge the correct amount of alkali for the given amount of chip mass in the digester. The trim tank configuration has the added advantage of allowing adjustments to white liquor sulfidity as well as EA, thus providing a means for incremental yield adjustments based on the cooking liquor composition.

DURALYZER-NIR .vs. Current Solutions
The current online sensor of choice for this application is the conductivity meter. Automated titration is an option as well but tends to be cost prohibitive. More often than not manual testing is the primary white liquor analysis method. This is primarily due to the fact that conductivity is a single point measurement and as such is only an indication of white liquor effective alkali. However, conductivity is also sensitive to variations in white liquor sulfidity, carbonate and other dead-load ionic species as well. Variations in these components require periodic manual testing to compensate for these variations within the instrument. The result is that the conductivity meter is recalibrated after each manual test to minimize this induced drift. If a sudden change in sulfidity or carbonate levels is experienced between manual tests the conductivity meter will report an incorrect effective alkali level in the white liquor, leading to an incorrect white liquor charge into the digester. The ***DURALYZER-NIR*** analyzer eliminates this issue since sulfide, carbonate and dead-load levels are directly measured along with the effective alkali. The ***DURALYZER-NIR*** analyzer allows the mill to drastically reduce manual testing of white liquor by operators to a weekly or monthly activity. With manual testing reduced to this level the analyzer can be validated by the mill’s main lab to eliminate operator bias in this testing procedure. A table detailing the primary advantages of the ***DURALYZER-NIR*** white liquor analyzer compared to current practices is given on the following page.

Online Liquor Analyzers
White Liquor Analyzer



DURALYZER-NIR White Liquor Analyzer .vs. Conductivity

Characteristic	Conductivity Meter	DURALYZER-NIR White Liquor Analyzer
Available Measurements	1 - WL - EA	6 - WL - EA, AA, TTA, TDS, TDD, TSS
Measurement Technique	Inferred – Solution conductivity correlated to WL - EA	Inferred – PLS regression technique based on TAPPI test methods (Regression model relating spectral signature to chemical composition)
Maintenance - Analyzer	High – Constant recalibration, potential scale buildup issues	Very Low – Yearly light source replacement, occasional lab validation
Maintenance - Sampling System	N/A	Very Low – 1 - 2 year valve servicing, 1-6 month cleaning acid replacement
Analysis Speed	Fast – Continuous update	Moderate – Three minute update cycle
Total Installed Cost	**Low**	**Low - Moderate**

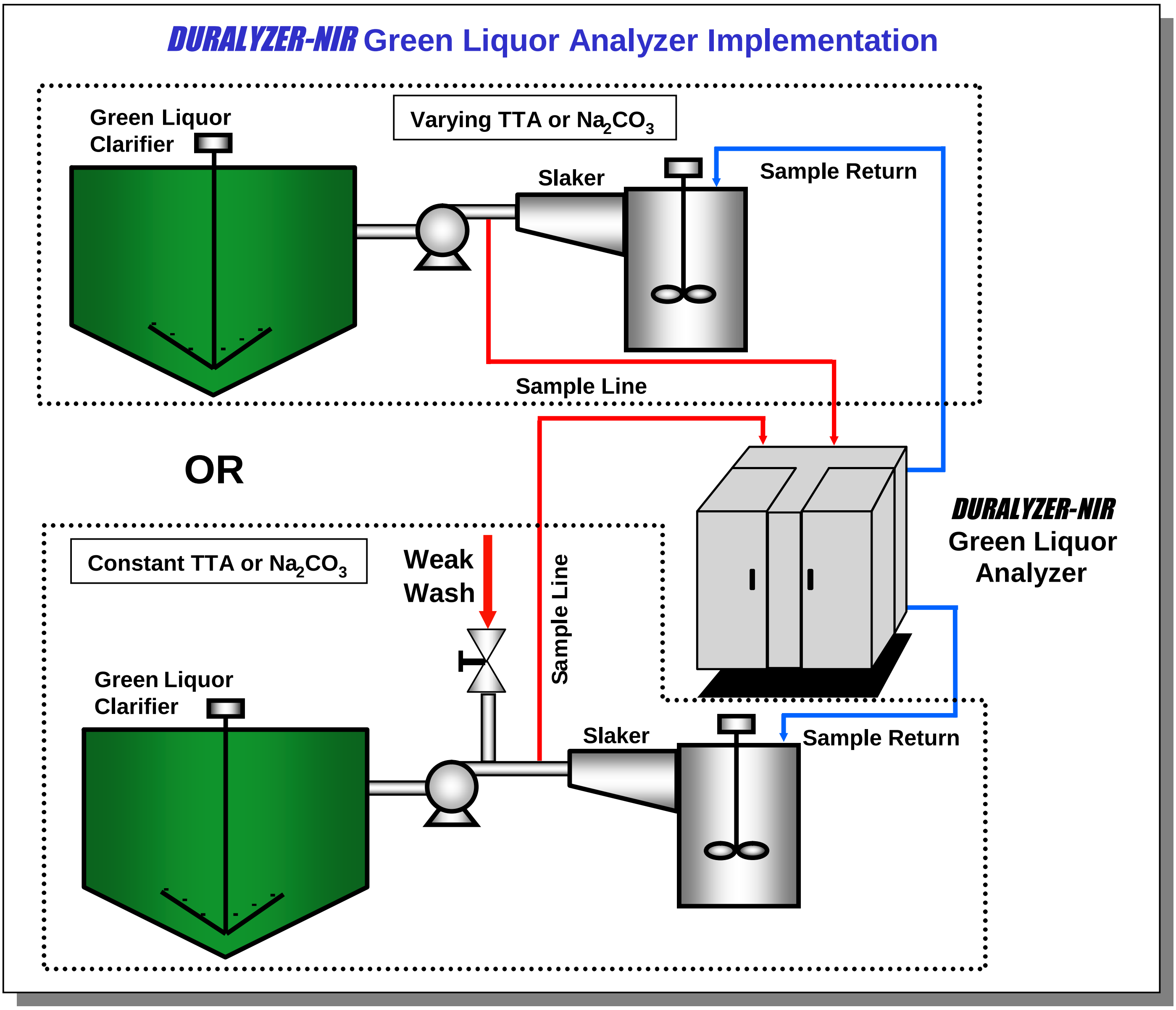
Online Liquor Analyzers
Green Liquor Analyzer

Introduction
Reliable and accurate green liquor analysis for the slaking process is important for optimizing lime usage. Green liquor sodium carbonate (Na_2CO_3) levels need to be accurately known to ensure the correct amount of lime is dosed for the incoming green liquor. The two primary sources of variation that interfere with dosing the correct amount of lime on green liquor are lime quality variations and green liquor variations. If the green liquor composition is accurately known then one source of variation can be eliminated. With an online green liquor analyzer the green liquor can be trimmed in real time to meet target total titrateable alkali (TTA) or Na_2CO_3 levels allowing one to maintain a lime feed rate that depends only on green liquor throughput leading to reduced variations in lime screw speed. Alternatively, variations in green liquor composition can be used along with green liquor flow rate to determine the required lime dosing. Either approach requires an accurate online analysis of the green liquor entering the slaker. The DURALYZER-NIR green liquor analyzer provides the required active alkali (AA) and TTA measurements in a timely, accurate and reliable manner. Additionally, green liquor effective alkali (EA), total dissolved solids (TDS) and total dissolved dead-load (TDD) levels are also available from the same analyzer.

Application Details
The graphic on the following page shows how the ***DURALYZER-NIR*** green liquor analyzer can be implemented for monitoring and/or controlling the composition of the green liquor entering the slaker. Two possible configurations are given in the graphic. The varying TTA or Na_2CO_3 configuration monitors the green liquor composition and uses these measurements along with green liquor flow rate to determine the appropriate amount of lime to be dosed. The second configuration provides a means by which the green liquor TTA or Na_2CO_3 levels can be trimmed using weak wash to achieve a constant green liquor composition so that lime dosing into the slaker depends only on the green liquor throughput. The goal of both configurations is to dose the correct amount of lime on the green liquor entering the slaker. The constant TTA or Na_2CO_3 configuration has the added advantage of minimizing lime screw speed variations further reducing ware on process equipment. Note that these techniques provide a means of feed-forward control of the causticizing process and do not take lime quality variations into account. To implement a feed-forward feed-back control arrangement for the causticizing process look at the ***DURALYZER-NIR*** Causticizing analyzer section.

DURALYZER-NIR .vs. Current Solutions
The current online sensors of choice for this application are the refractive index (RI) meter and density meter. Automated titration is an option as well but tends to be cost prohibitive for a single sample line measurement. More often than not manual testing is the primary green liquor analysis method. This is primarily due to the fact that implementing refractive index or density measurements at this location requires periodic removal and cleaning of the sensors to eliminate scale buildup. High pressure washing or steam cleaning has to be implemented along with the sensor to reduce this maintenance issue. The brute force approaches of these cleaning methods can lead to damage of the sensor heads requiring unplanned maintenance. Like the conductivity measurement, refractive index and density are single point measurements and as such are only an indicator of green liquor TTA. Both approaches give a TDS estimate from which TTA is inferred. Neither approach can provide a direct sodium carbonate measurement. The ***DURALYZER-NIR*** green liquor analyzer eliminates all of these issues by providing a direct TTA and AA measurement from which a direct sodium carbonate measurement can be obtained. The automated acid cleaning system that is standard on all ***DURALYZER-NIR*** models eliminates any scale buildup from the sensor head so the end user does not have to deal with manual cleaning or the design and maintenance of a brute force cleaning method. The ***DURALYZER-NIR*** green liquor analyzer allows the mill to drastically reduce manual testing of green liquor by operators to a weekly or monthly activity. With manual testing reduced to this level the analyzer can be validated by the mill's main lab to eliminate operator bias in this testing procedure. A table detailing the primary advantages of the ***DURALYZER-NIR*** green liquor analyzer compared to current practices is given on the following page.

Online Liquor Analyzers
Green Liquor Analyzer



DURALYZER-NIR Green Liquor Analyzer .vs. Refractive Index & Density

Characteristic	Refractometer	Density Meter	DURALYZER-NIR Greeen Liquor Analyzer
Available Measurements	1 - GL - TTA	1 - GL - TTA	5 - GL - EA, AA, TTA, TDS, TDD
Measurement Technique	Inferred – GL-Ref. Index correlated to GL - TDS, correlated to GL - TTA	Inferred – GL-Density correlated to GL - TDS, correlated to GL - TTA	Inferred – PLS regression technique based on TAPPI test methods (Regression model relating spectral signature to chemical composition)
Measurement Resolution	Good	Average	Excellent
Maintenance - Analyzer	High – Manual cleaning or automated steam/ high pressure wash(1)	High – Manual cleaning or automated steam/ high pressure wash(1)	Very Low – Yearly light source replacement, occasional lab validation
Maintenance - Sampling System	N/A	N/A	Very Low (2) – 1 - 2 year valve servicing
Analysis Speed	Fast – Continuous update	Fast – Continuous update	Moderate – Three minute update cycle
Total Installed Cost	**Low - Moderate(3)**	**Low - Moderate(3)**	**Low - Moderate**

1. Automated cleaning system is implemented by the mill. Brute force cleaning methods can lead to sensor head damage.
2. Integrated acid cleaning system requires only that acid be refreshed every 1-6 months depending on level of scaling. Cleaning system has no adverse effects on sensor head.
3. Total installed cost and operating cost can increase substantially depending on design and implementation of automated cleaning system.

Online Liquor Analyzers
Dissolving/Stabilization Tank Analyzer

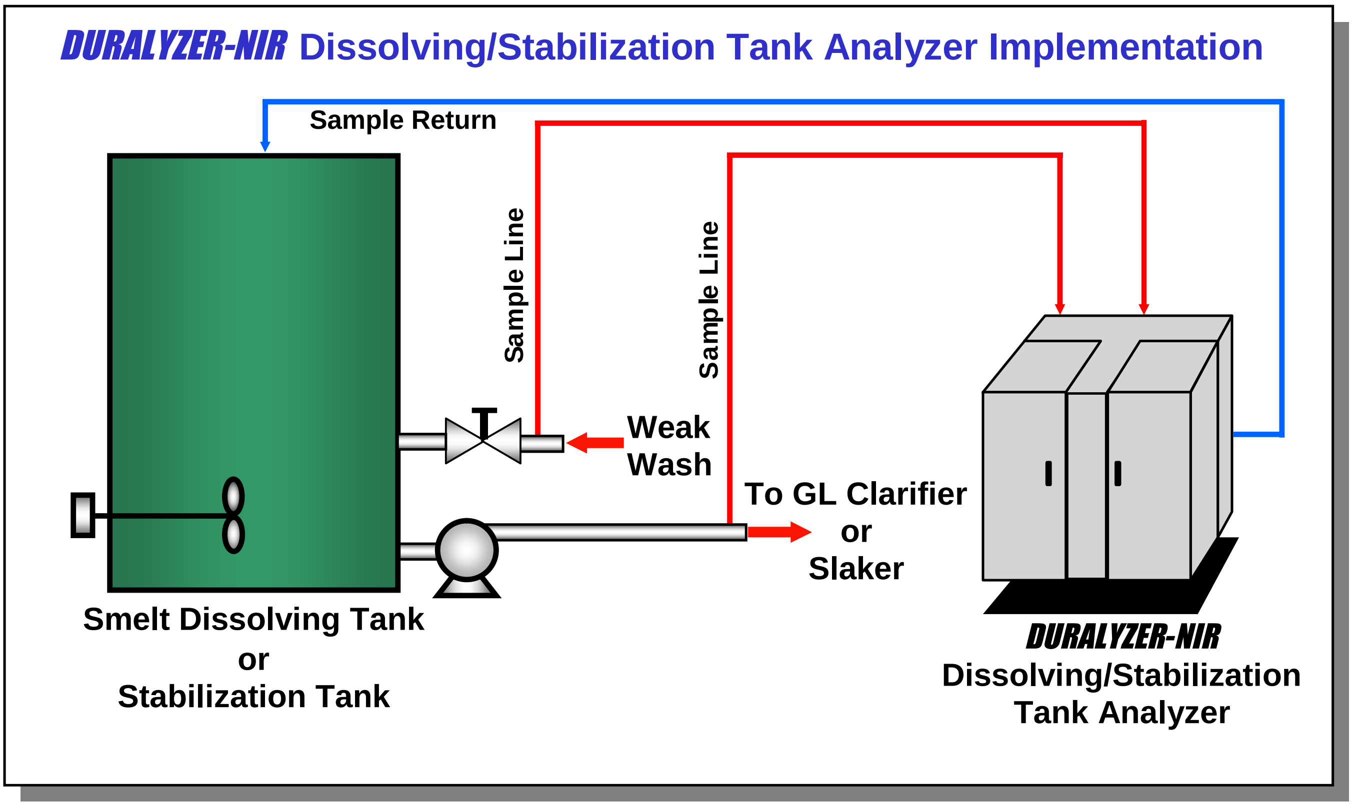
Introduction
Reliable and accurate liquor analysis at the dissolving tank and stabilization tank locations is key to controlling the quality of the green liquor that is sent to the causticizing process. Stabilizing the green liquor composition as much as possible at these locations ensure that variations in the down stream green liquor is minimized before reaching the recaust area. Stabilization of the green liquor at the dissolving tank is also important for controlling the settling characteristics of the liquor and minimizing scale buildup in piping and process equipment. It is desirable to maintain green liquor TTA in as tight a range as possible; to high a TTA can lead to scaling issues, to low a TTA leads to reactivity issues at the slaker. With an online dissolving/stabilization tank analyzer the green liquor composition can be controlled in real time to meet target TTA or Na_2CO_3 levels. In addition to the green liquor analysis provided by this analyzer, weak wash TTA is also provided allowing for a feedforward-feedback control arrangement. The ***DURALYZER-NIR*** dissolving/stabilization tank analyzer provides the required green liquor AA and TTA measurements in a timely, accurate and reliable manner for green liquor composition control. Additionally, green liquor EA, TDS, TDD and RE are also available from the same analyzer as well as the weak wash TTA measurement.

Application Details
The graphic on the following page shows how the ***DURALYZER-NIR*** **dissolving/stabilization tank** analyzer can be implemented for controlling the composition of the green liquor exiting these tanks. The graphic shows a two sample line arrangement; one line for green liquor the other for weak wash. The standard analyzer configuration comes with three sample lines. This allows the analyzer to also be connected to the spare line that most dissolving tank arrangements are equipped with. A signal from the DCS or a PLC is used to communicate to the analyzer the current flow configuration (i.e. which is the green liquor line and which is the weak wash line). A feedback control signal based on green liquor TTA or Na_2CO_3 levels can then be used to adjust weak wash flow to maintain target TTA or Na_2CO_3 levels. The combination green liquor analysis and weak wash analysis from the analyzer can be used for stabilization tanks to get tight control over the green liquor composition using a feedforward-feedback control arrangement. Dissolving tank analysis is unique among the liquor analysis applications due to the rapid step changes that can occur from smelt rush conditions. In addition, scaling at this location can also be a serious issue, quickly fouling other sensor solutions to a degree that makes them inoperable. The ***DURALYZER-NIR*** **analyzer solves both of these issues. Green liquor analysis results can be provided in as short a time as a three minute cycle. Special Teflon lined sample taps ensure that the tap locations do not scale up to a degree that would interfere with collecting a valid process sample.**

DURALYZER-NIR .vs. Current Solutions
The current online sensors of choice for this application are the refractive index (RI) meter and density meter. Automated titration is an option as well but tends to be cost prohibitive. Slow analysis speed of automated titration is also a major drawback for this application. More often than not manual testing is the primary green liquor analysis method. This is primarily due to the fact that implementing refractive index or density measurements at this location requires periodic removal and cleaning of the sensors to eliminate scale buildup. High pressure washing or steam cleaning has to be implemented along with the sensor to reduce this maintenance issue. The brute force approaches of these cleaning methods can lead to damage of the sensor heads requiring unplanned maintenance. Like the conductivity measurement, refractive index and density are single point measurements and as such are only an indicator of green liquor TTA. Both approaches give a TDS estimate from which TTA is inferred. Neither approach can provide a direct sodium carbonate measurement. The ***DURALYZER-NIR*** dissolving/stabilization tank analyzer eliminates all of these issues by providing a direct TTA and AA measurement from which a direct sodium carbonate measurement can be obtained. The automated acid cleaning system that is standard on all ***DURALYZER-NIR*** models eliminates any scale buildup from the sensor head so the end user does not have to deal with manual cleaning or the design and maintenance of a brute force cleaning method. A table detailing the primary advantages of the ***DURALYZER-NIR*** white liquor analyzer compared to current practices is given on the following page.

DURALYZER-NIR .vs. Current Solutions

The **DURALYZER-NIR** dissolving/stabilization tank analyzer allows the mill to drastically reduce manual testing of green liquor by operators to a weekly or monthly activity. With manual testing reduced to this level the analyzer can be validated by the mill's main lab to eliminate operator bias in this testing procedure. A table detailing the primary advantages of the **DURALYZER-NIR** green liquor analyzer compared to current practices is given on the following page.



Online Liquor Analyzers
Dissolving/Stabilization Tank Analyzer

DURALYZER-NIR Green Liquor Analyzer .vs. Refractive Index & Density

Characteristic	Refractometer	Density Meter	DURALYZER-NIR Greeen Liquor Analyzer
Available Measurements	1 - GL - TDS	1 - GL - TDS	7 - GL - EA, AA, TTA, TDS, TDD, RE & WW - TTA
Measurement Technique	Inferred – GL-Ref. Index correlated to GL - TDS, correlated to GL - TTA	Inferred – GL-Density correlated to GL - TDS, correlated to GL - TTA	Inferred – PLS regression technique based on TAPPI test methods (Regression model relating spectral signature to chemical composition)
Measurement Resolution	Good	Average	Excellent
Maintenance - Analyzer	High – Manual cleaning or automated steam/ high pressure wash(1)	High – Manual cleaning or automated steam/ high pressure wash(1)	Very Low – Yearly light source replacement, occasional lab validation
Maintenance - Sampling System	N/A	N/A	Very Low (2) – 1 - 2 year valve servicing
Analysis Speed	Fast – Continuous update	Fast – Continuous update	Moderate – Three minute update cycle
Total Installed Cost	**Low - Moderate(3)**	**Low - Moderate(3)**	**Low - Moderate**

1. Automated cleaning system is implemented by the mill. Brute force cleaning methods can lead to sensor head damage.
2. Integrated acid cleaning system requires only that acid be refreshed every 1-6 months depending on level of scaling. Cleaning system has no adverse effects on sensor head.
3. Total installed cost and operating cost can increase substantially depending on design and implementation of automated cleaning system.

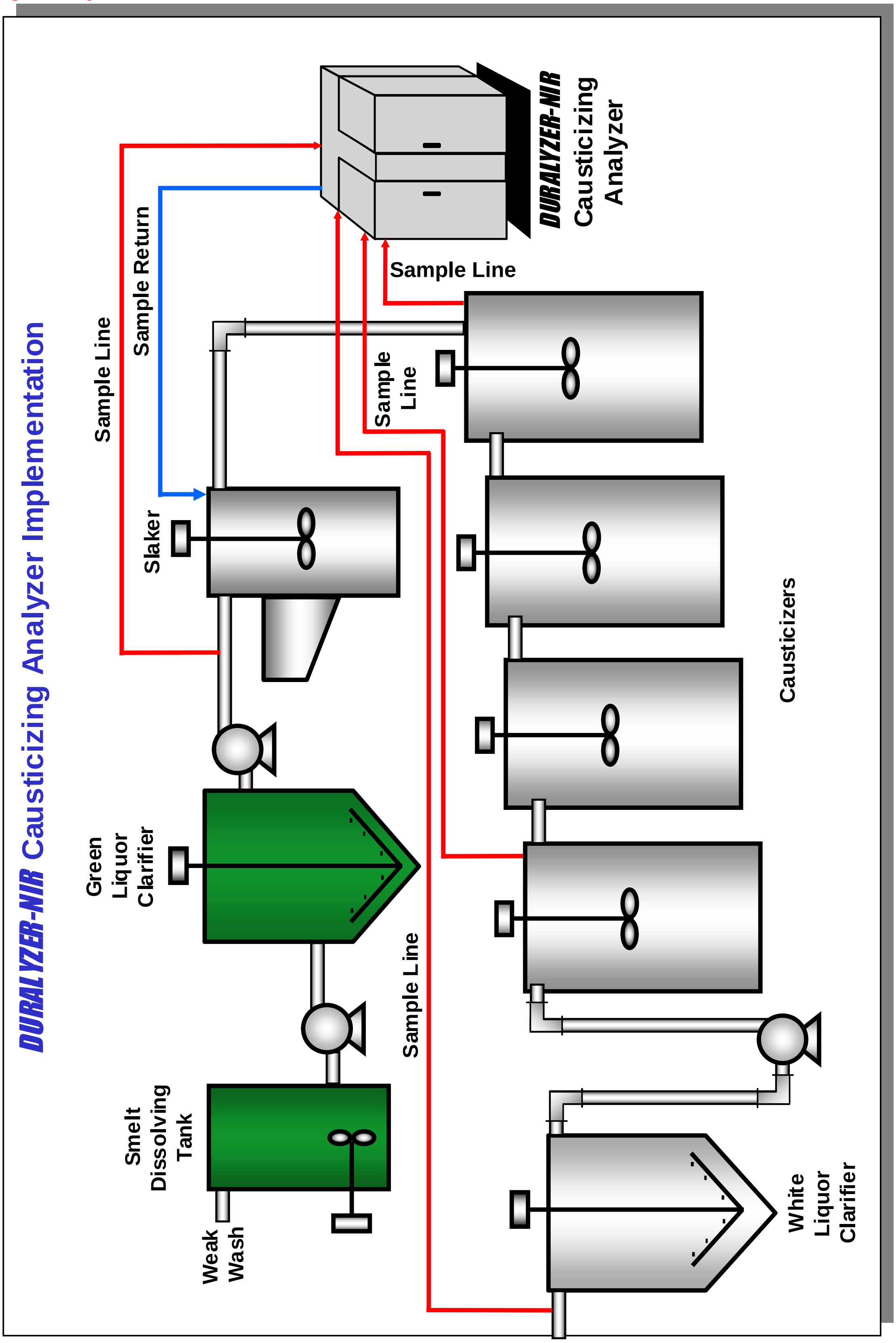
Online Liquor Analyzers
Causticizing Analyzer

Introduction
Reliable and accurate white and green liquor analysis at key locations in the causticizing process is required to produce a stable high quality supply of cooking white liquor. Variations in green liquor composition and variations in lime quality require an online measurement solution to optimize control of the causticizing process. Operating the process at the highest CE% possible without overliming is very difficult based on manual tests and delta-T control. Measurements for green liquor carbonate levels going into the slaker and white liquor composition downstream provide the necessary information to compensate for the majority of the process variations that will be experienced in practice. Green liquor composition measurements coming into the slaker provides the Na_2CO_3 measurement necessary for feedforward control of the lime screw while white liquor EA measurements in the slaker and downstream causticizers provide the feedback information relating to lime quality variations. Since all of the component concentrations for each sample point is available from the analyzer, CE% can be computed directly. The ***DURALYZER-NIR*** analyzer solution easily provides these measurements in a timely and reliable manner. Additionally, TDS and TDD measurements are also available for each sample stream.

Application Details
The graphic on the following page shows how the ***DURALYZER-NIR*** causticizing analyzer can be implemented for feedforward-feedback control of the causticizing process. The standard configuration for this analyzer is a four sample line arrangement. One sample line monitors the green liquor coming into the slaker, one line monitors the white liquor exiting the slaker or first causticizer, one line monitors the white liquor exiting a downstream causticizer and one line monitors the clarified white liquor. This arrangement gives the necessary green liquor and white liquor analysis needed for a feedforward-feedback control arrangement. Other configurations are possible supporting up to eight (8) sample lines. A specially designed vacuum system draws slurry samples from the slaker and causticizers eliminating the need for special pumps to deliver the sample from these locations to the analyzer. All samples flow from the process through the analyzer and directly back into the process.

DURALYZER-NIR .vs. Current Solutions
The current online sensors of choice for this application are automated titrater based solutions and differential conductivity based solutions. Both of these solutions have a high total installed cost and a high long term cost of ownership due to high maintenance demands for these systems. In addition, differential conductivity methods only provide an inferred CE% measurement since conductivity meters are single point instruments as described in previous sections. CE% is estimated using neural networks or some other nonlinear modeling method to provide an estimate based on conductivity differences between different tanks in the process. Conductivity probes are distributed throughout the process and may require periodic removal and cleaning to deal with scale buildup issues. Titrater based solutions tend to be complicated in their implementation. A deionized water system, weekly replacement of standardized reagent grade HCl solution and periodic valve and diaphragm pump replacement all contribute to the high maintenance requirement for these systems. Special housing requirements for the titrater system contribute greatly to the total installed cost of this device. The ***DURALYZER-NIR*** causticizing analyzer eliminates all of these issues in one compact, cost effective, turnkey solution. The automated acid cleaning system that is standard on all ***DURALYZER-NIR*** models eliminates any scale buildup from the sensor head so the end user does not have to deal with manual cleaning. A minimized hardware arrangement based on proprietary high cycle life valves and vacuum system ensure that the sampling system performs with near zero maintenance requirements. The vortex cooling system and packaging of ***DURALYZER-NIR*** analyzers allow them to sit in the most convenient location of the process area as delivered, greatly reducing installation costs and total installed cost. Additionally, EA, AA and TTA measurements are provided for each sample stream so that all causticizing process parameters can be directly calculated. A table detailing the primary advantages of the ***DURALYZER-NIR*** **causticizing** analyzer compared to current solutions is given on the following page.

Online Liquor Analyzers
Causticizing Analyzer



DURALYZER-NIR Causticizing Analyzer .vs. Titraters and Differential Conductivity

Characteristic	Autotitrater	Diff. Conductivity	DURALYZER-NIR Causticizing Analyzer
Available Measurements	3 - EA, AA, TTA (all streams)	1 - Inferred CE%	5 - EA, AA, TTA, TDS, TDD (all streams)
Measurement Technique	Inferred – SCAN method (inflection point search of pH titration curve)[1]	Inferred – CE% correlated to differential conductivity	Inferred – PLS regression technique based on TAPPI test methods (Regression model relating spectral signature to chemical composition)
Complexity	High - Deionized water system, many moving parts	Low - multiple probes	Moderate - mostly solid state device
Maintenance - Analyzer	High – Weekly acid replacement, pH probe calibration, deionized water system maintenance	Moderate/High - Periodic manual cleaning of probes	Very Low – Yearly light source replacement, occasional lab validation
Maintenance - Sampling System	High - 6 month valve replacement, periodic diaphragm pump replacement	N/A	Very Low [(2)] – 1 - 2 year valve servicing
Analysis Speed	Moderate – Sample, settle and analyze cycle	Fast – Continuous update	Moderate/Fast – Sample, fast settle and fast analyze cycle
Total Installed Cost	**High -** Special housing, requirements, special sample line requirements	**Moderate - High**	**Low - Moderate in comparison**

1. AA inflection point is sensitive to deadload changes, especially changes in Na_2SO_3, leading to erroneous results in Na_2S and Na_2CO_3 estimates.
2. Integrated acid cleaning system requires only that acid be refreshed every 1-6 months depending on level of scaling.

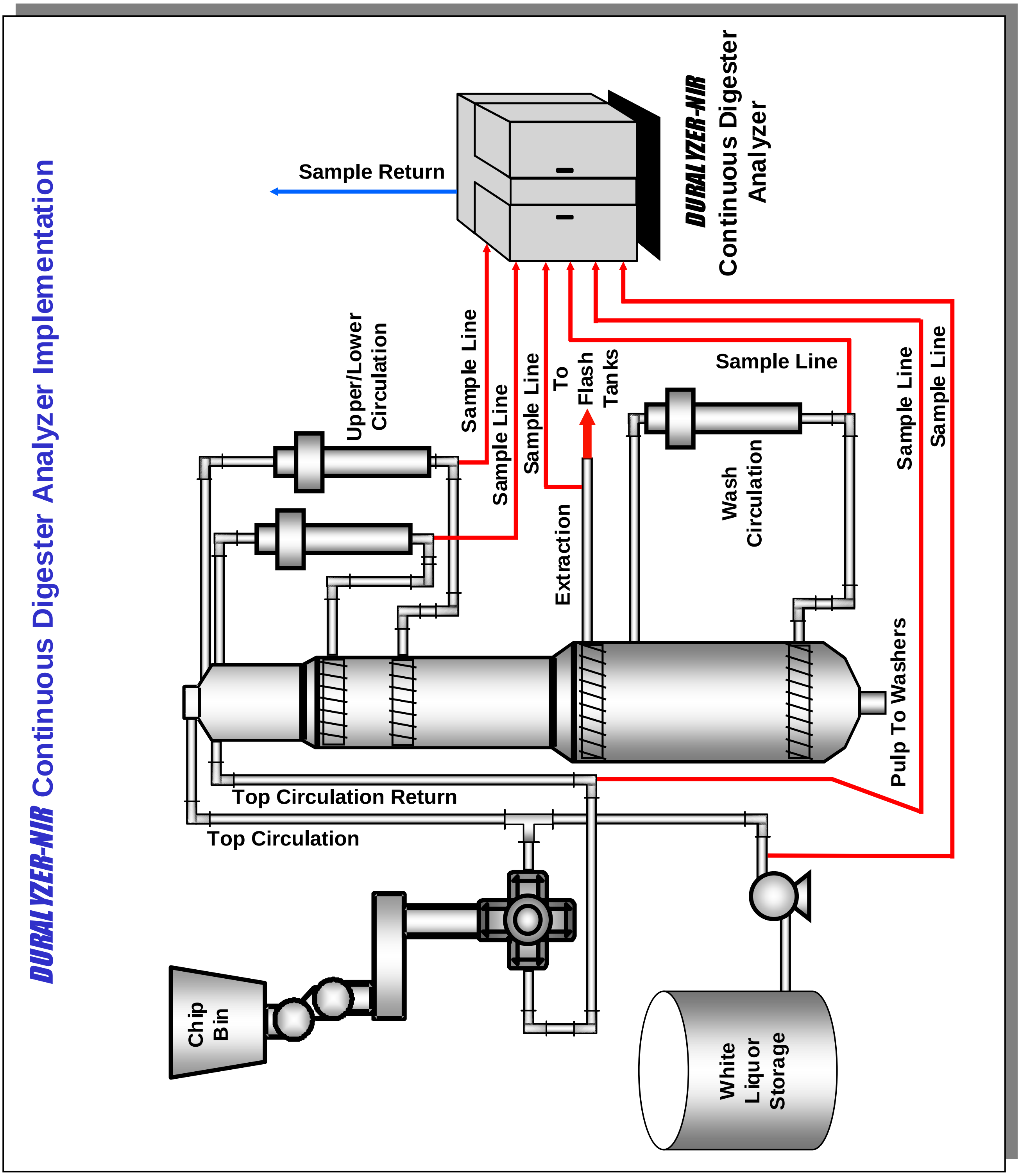
Online Liquor Analyzers
Continuous Digester Analyzer

Introduction
Monitoring black liquor composition in a continuous digester provides a means for implementing advanced control schemes in the pulping process. The residual EA profile is an indicator of exiting kappa number, the residual AA profile, lignin profile and TDS profile are indicators of exiting pulp yield. By monitoring and stabilizing these profiles in a continuous digester pulp quality variations can be greatly reduced while maintaining a maximum yield. Digesters running standard cooks can compensate for residual EA variations by adjusting the temperatures in the cooking zones. Variations in residual EA can also be compensated for by trimming the incoming white liquor or adjusting the liquor to wood ratio. Continuous digesters fitted with liquor feed points in the cooking zones have the added flexibility of accurately and quickly controlling the residual EA profile throughout the digester by directly injecting white liquor into these zones. Controlling the residual EA profile and cooking conditions in a continuous digester by either method requires reliable and accurate measurements. The ***DURALYZER-NIR*** analyzer solution easily provides these measurements in a timely and reliable manner. Additionally, residual AA, lignin and TDS measurements are also available from the same analyzer. Black liquor composition contains a wealth of information relating to various pulp properties. The ***DURALYZER-NIR*** analyzer captures this information in the spectral signature of the black liquor sample. So in addition to providing the previously mentioned measurements, a variety of pulp properties (e.g. kappa number and relative yield) can be directly correlated to the liquor spectral signature.

Application Details
The graphic on the following page shows how the ***DURALYZER-NIR*** **continuous digester analyzer is implemented on a Kamyr digester running a standard kraft cook.** Similar arrangements would also apply for MCC and EMCC digesters. This implementation has six sample lines, monitoring the incoming white liquor, liquor return, upper and lower cooking zones, extraction zone and the incoming filtrate liquor. All samples flow from the process through the analyzer and directly back into the process. This arrangement gives a complete picture of the digestion process from the perspective of liquor composition variations. Other arrangements supporting different digester arrangements are available supporting up to eight (8) sample lines. Proprietary filters combined with a high pressure backflush system ensure that line plugging due to chip debris does not interfere with sample collection. Proprietary high cycle life valves ensure that valve maintenance is not required for two or more years. White liquor EA, AA, TTA & TDS measurements are provided for white liquor and return liquor lines. Black liquor REA, RAA, lignin & TDS are provided for all of the black liquor streams.

DURALYZER-NIR .vs. Current Solutions
Current sensors for this application include hybrid systems composed of some arrangement of a refractometer, conductivity meter and UV absorption meter. Online titraters are another option for this application. Titraters are limited to measuring only residual EA, however. A major drawback to these hybrid systems is that each meter has to be calibrated for the particular component that it will be measuring. Additionally, since this sensor is a collection of single point measurements it is susceptible to the same drift issues as conductivity meters are for white liquor analysis. Online titraters can measure residual EA using an automated version of the manual residual EA test, however, this is usually the only measurement that is available. Maintenance requirements for an online titrater are also quite high for this application. The combination of limited measurements and excessive maintenance requirements make it difficult to justify the capital investment for a titration based solution. The ***DURALYZER-NIR*** digester analyzer solution provides the collection of measurements that the hybrid sensor provides in one low maintenance, cost effective instrument. A table detailing the primary advantages of the ***DURALYZER-NIR*** continuous digester analyzer compared to current technologies is given on the following page.

Online Liquor Analyzers
Continuous Digester Analyzer



Online Liquor Analyzers
Continuous Digester Analyzer

DURALYZER-NIR Digester Analyzer .vs. Titraters and Hybrid Systems

Characteristic	Autotitrater	Hybrid Systems	DURALYZER-NIR Digester Analyzer
Available Measurements	1 - BL - REA	3 - BL-REA, Lignin, TDS	4 - WL - EA, AA, TTA, TDS 4 - BL - REA, RAA, Lignin, TDS
Measurement Technique	Inferred – SCAN method (inflection point search of pH titration curve)	Inferred – RI for TDS, Conductivity for REA, UV Absorbance for lignin	Inferred – PLS regression technique based on TAPPI test methods (Regression model relating spectral signature to chemical composition)
Complexity	High - Deionized water system, many moving parts	High - Multiple single point instruments, dilution system for UV	Moderate - mostly solid state device
Maintenance - Analyzer	High – Weekly acid replacement, pH probe calibration, deionized water system maintenance	High - Periodic recalibration of single point instruments	Very Low – Yearly light source replacement, occasional lab validation
Maintenance - Sampling System	High - 6 month valve replacement	High - 6 month valve replacement	Very Low (2) – 1 - 2 year valve servicing
Analysis Speed	Moderate – Sample, analyze cycle	Moderate – Sample, analyze cycle	Moderate/Fast – Sample, fast analyze cycle
Total Installed Cost	**High -** Special housing, requirements, special sample line requirements	**Moderate - High**	**Low - Moderate in comparison**

1. AA inflection point is sensitive to deadload changes, especially changes in Na_2SO_3, leading to erroneous results in Na_2S and Na_2CO_3 estimates.
2. Integrated acid cleaning system requires only that acid be refreshed every 1-6 months depending on level of scaling.

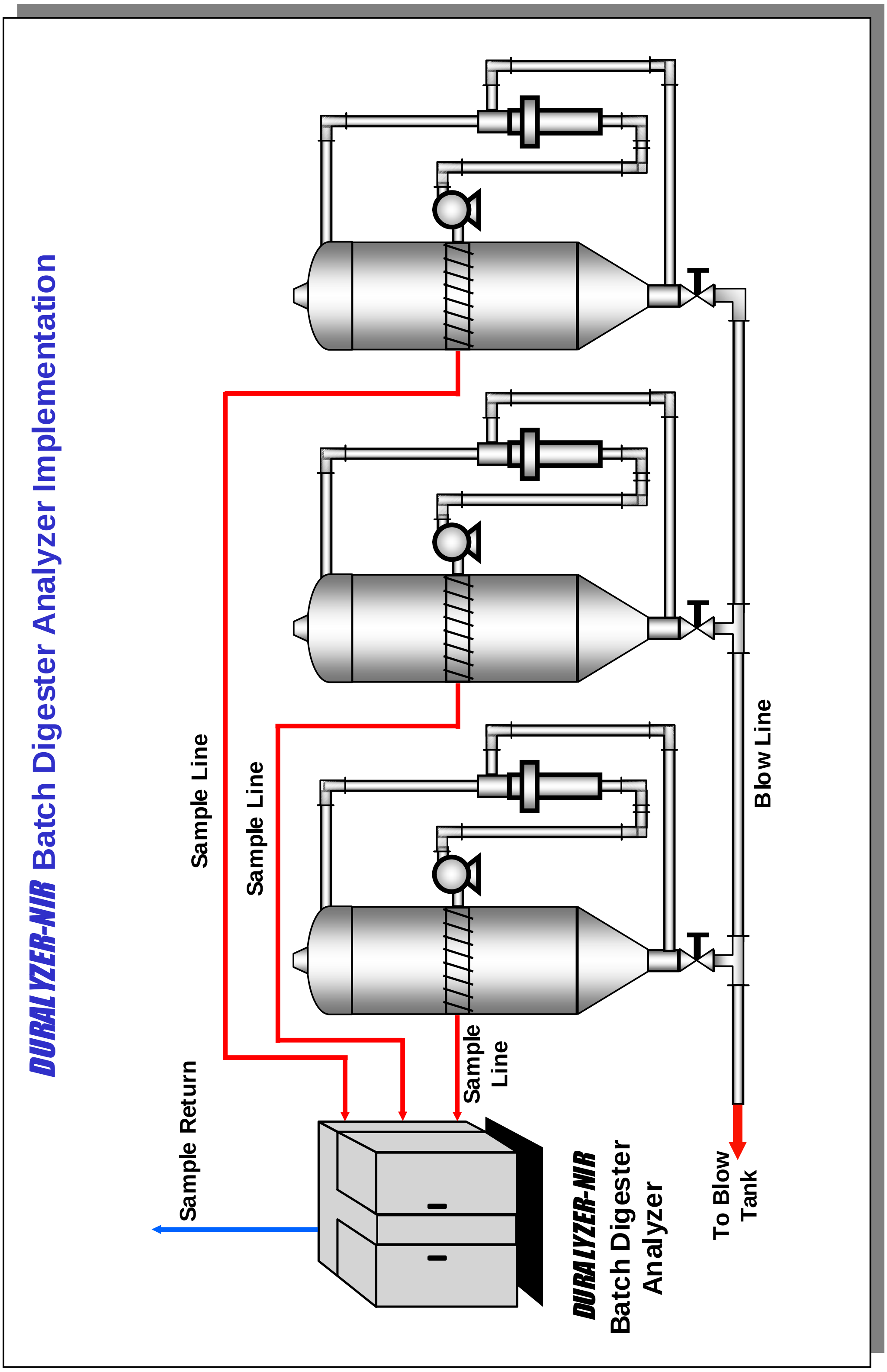
Online Liquor Analyzers
Batch Digester Analyzer

Introduction
Similar to the continuous digester, monitoring black liquor composition in a batch digester provides a means for implementing advanced control schemes in the pulping process. As in the continuous case, the residual EA profile is an indicator of exiting kappa number, the residual AA profile, lignin profile and TDS profile are indicators of exiting pulp yield. The primary difference being that in the batch case these profiles are a function of time instead of space. These time varying profiles can be correlated to the average kappa and yield of the exiting pulp or a mass balance model can be used to directly calculate kappa and yield during the course of the cooking process. Monitoring of the EA profile during temperature ramp up allows the alkali to wood ratio to be trimmed prior to sealing the digester, resulting in a more consistent charge of cooking chemicals for each cook. Black liquor composition contains a wealth of information relating to various pulp properties. The ***DURALYZER-NIR*** analyzer captures this information in the spectral signature of the black liquor sample. So in addition to providing the previously mentioned measurements, a variety of pulp properties (e.g. kappa number, relative yield and viscosity) can be directly correlated to the liquor spectral signature. Whatever advanced batch digester control scheme is implemented requires reliable and accurate measurements. The ***DURALYZER-NIR*** analyzer solution easily provides these measurements in a timely and reliable manner.

Application Details
The graphic on the following page shows how the ***DURALYZER-NIR*** **digester analyzer is implemented on batch digesters running a standard kraft cook.** Each digester has a dedicated sample line supplying the analyzer. All samples flow from the process through the analyzer and directly back into the process. One analyzer can support up to eight different digesters. Proprietary filters combined with a high pressure backflush system ensure that line plugging due to chip debris does not interfere with sample collection. Proprietary high cycle life valves ensure that valve maintenance is not required for two or more years. Black liquor REA, RAA, lignin & TDS are provided for each connected digester.

DURALYZER-NIR .vs. Current Solutions
Current sensors for this application are the same as for the continuous digester case and include hybrid systems composed of some arrangement of a refractometer, conductivity meter and UV absorption meter. Online titraters are another option for this application. Titraters are limited to measuring only residual EA, however. A major drawback to these hybrid systems is that each meter has to be calibrated for the particular component that it will be measuring. Additionally, since this sensor is a collection of single point measurements it is susceptible to the same drift issues as conductivity meters are for white liquor analysis. Online titraters can measure residual EA using an automated version of the manual residual EA test, however, this is usually the only measurement that is available. Maintenance requirements for an online titrater are also quite high for this application. The combination of limited measurements and excessive maintenance requirements make it difficult to justify the capital investment for a titration based solution. The ***DURALYZER-NIR*** digester analyzer solution provides the collection of measurements that the hybrid sensor provides in one low maintenance, cost effective instrument. A table detailing the primary advantages of the ***DURALYZER-NIR*** batch digester analyzer compared to current technologies is given on the following page.

Online Liquor Analyzers
Batch Digester Analyzer



DURALYZER-NIR Digester Analyzer .vs. Titraters and Hybrid Systems

Characteristic	Autotitrater	Hybrid Systems	DURALYZER-NIR Digester Analyzer
Available Measurements	1 - BL - REA	3 - BL-REA, Lignin, TDS	4 - WL - EA, AA, TTA, TDS 4 - BL - REA, RAA, Lignin, TDS
Measurement Technique	Inferred – SCAN method (inflection point search of pH titration curve)	Inferred – RI for TDS, Conductivity for REA, UV Absorbance for lignin	Inferred – PLS regression technique based on TAPPI test methods (Regression model relating spectral signature to chemical composition)
Complexity	High - Deionized water system, many moving parts	High - Multiple single point instruments, dilution system for UV	Moderate - mostly solid state device
Maintenance - Analyzer	High – Weekly acid replacement, pH probe calibration, deionized water system maintenance	High - Periodic recalibration of single point instruments	Very Low – Yearly light source replacement, occasional lab validation
Maintenance - Sampling System	High - 6 month valve replacement	High - 6 month valve replacement	Very Low (2) – 1 - 2 year valve servicing
Analysis Speed	Moderate – Sample, analyze cycle	Moderate – Sample, analyze cycle	Moderate/Fast – Sample, fast analyze cycle
Total Installed Cost	**High -** Special housing, requirements, special sample line requirements	**Moderate - High**	**Low - Moderate in comparison**

1. AA inflection point is sensitive to deadload changes, especially changes in Na_2SO_3, leading to erroneous results in Na_2S and Na_2CO_3 estimates.
2. Integrated acid cleaning system requires only that acid be refreshed every 1-6 months depending on level of scaling.